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The Biofield Hypothesis: Its Biophysical Basis and Role in Medicine

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ABSTRACT

This paper provides a scientific foundation for the biofield: the complex, extremely weak electromagnetic field of the organism hypothesized to involve electromagnetic bioinformation for regulating homeodynamics. The biofield is a useful construct consistent with bioelectromagnetics and the physics of nonlinear, dynamical, nonequilibrium living systems. It offers a unifying hypothesis to explain the interaction of objects or fields with the organism, and is especially useful toward understanding the scientific basis of energy medicine, including acupuncture, biofield therapies, bioelectromagnetic therapies, and homeopathy. The rapid signal propagation of electromagnetic fields comprising the biofield as well as its holistic properties may account for the rapid, holistic effects of certain alternative and complementary medical interventions.

INTRODUCTION

Over the past few decades, biochemistry and molecular biology have dominated biology and medicine. This approach, which is based on reductionism and a view of the body as a complex machine made of parts, is the basis of conventional biomedicine, with its sophisticated pharmacologic, surgical, and other powerful medical modalities that fight disease. This view culminated in the Human Genome Project that has elucidated less than 40,000 genes (Claverie, 2001) in the human genome, purportedly the key information that makes up the human being. It is surprising to find such a small number of genes, and some question whether the human genome is sufficient to account for all information specifying a human being (Strohman, 1983). Moreover, the genetic view of life is limited because it is unable to explain many of life's subtle characteristics, including the action of various complementary and alternative medicine (CAM) interventions.

The CAM therapies that appear to challenge the dominant biomedical paradigm typically involve subtle field interactions, such as biofield therapies, homeopathy, acupuncture, magnet therapy, bioelectromagnetic therapy, electrodermal therapy, and phototherapy, among others (Table 1). Collectively, these have been called, energy medicine. It is not well understood how these modalities work, which is one reason they remain outside the mainstream. An appropriate scientific foundation is important to advance the research, application, and acceptance of these and other CAM medical practices.

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Table 1. CAM Practices That May Involve Field Interactions

1. Acupuncture, electroacupuncture, laser acupuncture
2. Acupressure and reflexology
3. Bioelectromagnetic medicine
4. Electrodermal testing
5. Electrostimulation, electrotherapy
6. Biofield therapies (Reiki, Therapeutic Touch, Healing Touch, etc.)
7. Homeopathy
8. Bach flower remedies
9. Magnet therapy
10. Microwave resonance therapy
11. Low-level laser therapy
12. Phototherapy
13. Color therapy
14. Orgonomy

CAM, complementary and alternative medicine.

In relation to this, there is another scientific view of life based on biophysics. Living systems are regarded as complex, nonlinear, dynamic, self-organizing systems at a global or holistic level according to the principles of nonequilibrium thermodynamics of open systems and chaos theory. Living systems are constantly exchanging energy-with-information at multiple levels of organization with their surroundings in order to maintain themselves. They also possess emergent properties such as higher order relationships dependent on context and meaning that have effects on health, disease, and healing. This biophysical view of life provides the rudiments of a scientific foundation for CAM modalities involving the transfer of bioinformation carried by a small energy signal. This goes beyond the usual molecular concepts of bioinformation. This paper provides a scientific basis toward how these interventions may work by impacting directly the global regulatory processes of life rather than the physical structures of the body.

It is worthwhile to consider further the two scientific views of life mentioned above. On the one hand, conventional biology provides a reductionistic, analytical view of life based on molecules and on structure–function relationships.

On the other hand, the emerging biophysical view is a dynamic one that addresses the whole organism, its field interactions, and its integral flows of information in relation to the environment. Metaphorically speaking, conventional biology depicts life as a crystal, and the emerging biophysical view depicts life as a flame. Although both views are correct within a certain context, each alone is limited. Together they are complementary and provide a more complete view of life that offers greater potential for understanding health and healing. That is to say, the living state is richer and more complex than it is possible to express in a single model or metaphor.

A similar situation exists in physics in the theory of light. There it was necessary to formulate the principle of complementarity (Katsumori, 1998) to embrace light's dualistic properties of particles and waves. Either the particle or the wave model is invoked to explain particular scientific observations, depending on which description best fits the experimental data. This particle–wave duality also applies to all matter in quantum physics. It is timely for biology to move beyond Newtonian physics and embrace quantum theory, which originated a century ago. Therefore, we need to consider particle–wave duality for the constituents of life. On the one hand, life is made of complex biomolecular structures; on the other hand, it is dynamic waves with information. Whereas the molecular view of life provides a scientific basis for allopathic medicine, the field view offers a scientific foundation for many types of CAM modalities.

Some of the concepts in this paper may not be well known to biologists or CAM practitioners. Thus, the key terms and concepts are introduced as they relate to CAM and the thesis of this paper. These are: nonlinear dynamic systems theory; nonequibrium thermodynamics; dissipative structures; chaos theory; homeodynamics; bioinformation conveyed by electromagnetic signals; and a field model of life with the biofield central to its "energy anatomy." The ramifications for CAM and a test of the biofield hypothesis are also discussed.

BACKGROUND

Linear and nonlinear systems

General systems theory goes back to biologist and philosopher Ludwig von Bertalanffy,

who in 1930–1940 developed the groundwork for a systems approach (von Bertalanffy, 1968). A system is a number of different and interacting things that display collective behavior as an integrative whole, such as a cell, nucleus, tissue, organ, organ system, organism, family, etc. The living domain of nature can be regarded as a hierarchy or network of nested systems of organized complexity.

Linear systems express behavior that is strictly proportional; a plot of response versus stimulus is a straight line. Linear systems comprise modules that can be taken apart and put back together again and still behave exactly the same. Conventional biology and medicine often utilize linear thinking in the causal scheme of relationships in living systems. For example, linear thinking underlies gene therapy, with the insertion of genes into patients' cells purportedly to eliminate disease.

Nonlinear systems express relationships that are not strictly proportional and, in general, they cannot be reduced to distinct modules that can be taken apart and put back together again to yield the same behavior. These systems are characterized by a complex pattern of interactions that includes feedback. As a result of feedback loops, even the simplest nonlinear system can display bizarre and unpredictable dynamic behavior such as unexplained fluctuations and irregularities. The control theory of nonlinear systems shows that feedback processes and other numerous pathways of information flow serve to regulate behavior (Weiner, 1948).

Before the age of fast computers, everything was approximated to be linear so that the mathematics describing it could be solved, although it was recognized that most real systems including living systems were nonlinear. Indeed, linear causal molecular mechanisms still dominate conventional biomedicine, but by the 1960s, new physical theory emerged from nonequilibrium thermodynamics that embraced nonlinear phenomena.

Self-organizing systems

The physics of self-organizing systems was launched by Ilya Prigogine, Ph.D., Nobel Laureate in chemistry for his work in nonequilibrium thermodynamics (Prigogine, 1980), and Eric Jantsch (Jantsch, 1980), among others. They brought together general systems theory and principles of self-organization and showed how these concepts applied to living systems and humans. Some tenets are (Morowitz, 1968): (1) living systems are open systems exchanging energy, matter, and information with the environment in order to develop and maintain themselves; (2) open systems such as organisms that orchestrate flows of matter, energy, and information through themselves are self-organizing systems, far from equilibrium; (3) such systems dissipate energy in order to maintain themselves (dissipative structures) as quasi-stable macroscopic structures in space–time; (4) open systems typically display dynamic steady states that are quasi-stable or oscillate around steady-state values; (5) significant perturbations in living systems' dynamics can lead to disease and eventually death.

Self-organization through continuous flows of matter, energy, and information is the biophysical basis of life's autopoiesis, or self-maintenance and renewal. Life is continuously orchestrating its own dynamic pattern, and in doing so, is cognitive of itself (i.e., able to distinguish self from environment).

Self-organizing systems may undergo spontaneous internal fluctuations in their dynamics that, if near a critical point, may cause them to bifurcate to another dynamic state exhibiting new patterns of greater order or disorder. These fluctuations may be small in magnitude, but nonetheless powerful factors in generating new patterns of behavior. These new behavioral patterns may be the dynamic basis of disease or the basis of natural healing.

Self-organizing systems are also subject to external fluctuations or environmental signals that can also affect system behavior. Similar to internal fluctuations, changes in the environment can produce bifurcations in behavior and generate completely new modes of behavior. This may explain how medical modalities applied to the body, such as electromagnetic interventions that may interact directly with the system's dynamics, may nudge the organism dynamically into a healing state.

One important feature of living systems distinguishing them from the nonliving domain, including machines, is the large number of in-

tricate pathways along which information flows between all levels of organization, both ascending ("bottom-up") and descending ("top-down"). Medical interventions that interact with bioregulatory systems may act on any of these informational pathways. One limitation of conventional biomedicine is its bottom-up reductionist approach that precludes top-down approaches, because these are not strictly reducible to biochemical events.

Chaos theory

By the 1970s the chaos theory was born, largely as a result of physicists, mathematicians, meteorologists, engineers, and biologists working together to explore the behavior of nonlinear dynamic systems throughout nature. Chaos is defined as "organized disorder," (i.e., patterns of unpredictable irregularity displayed by even the simplest nonlinear system; Gleick, 1987). Chaotic systems in mathematics give rise to new, unexpected levels of order that are complex and richly patterned, sometimes stable and sometimes not, reminiscent of spontaneous patterns in nature. A simple example is the complex unpredictable pattern made by smoke rising from a pipe that can be changed drastically by the tiniest airflow.

Chaos theory goes a step further in addressing the dynamics of complex, nonlinear systems in showing that they display fundamental unpredictability. This theory extended self-organizing systems theory and nonequilibrium thermodynamics to more sophistication by including fractal geometry and the mathematics of evolutionary systems. Moreover, chaos theory uncovered the universality of all nonlinear dynamic systems in physics, biology, mathematics, and engineering. That is to say, nonlinear systems may exhibit precisely the same dynamics, even though they may consist of vastly different subcomponents at different scales of order. Despite this universality and the wide applicability to living systems, chaos theory has not yet had much impact yet on mainstream biology, biomedical thinking, or the practice of medicine.

The concepts of open, nonequilibrium, nonlinear, dynamic chaotic systems summarized briefly have important ramifications for biology and medicine. In the past, scientists neglected small stimuli to living systems. However, the new biophysics indicates that small fluctuations in the system dynamics or life's environment cannot be ignored because they may have significant, even drastic, effects. This has ramifications for bioregulatory processes and life's subtle interactions with the environment; for understanding certain CAM approaches to health assessment; and for understanding various CAM therapies, in particular, how the tiniest stimuli of energy medicine may promote dramatic effects on biologic regulation.

Two categories of medical interventions

It is proposed that medical interventions be considered categorically as follows: (1) structural interactions, and (2) regulatory interactions. Stimuli that do not recapitulate the dynamic processes or cognitive domain of the organism, but act structurally or mechanically on the organism, for example, to disrupt its structure or function in a gross fashion, are structural interactions. One example would be surgery to remove diseased tissue. Another would be radiation therapy to kill cancer. Many mainstream medical interventions are structural.

Stimuli that reiterate or partially realize the innate dynamics of the organism may communicate information to the organism, evoking corresponding shifts in dynamic processes. Medical interventions that act informationally utilize stimuli that are extremely small in intensity. They are small nudges that act in accordance with the organism's natural system dynamics to restore balance and harmony. Examples of such medical modalities may include acupuncture, homeopathy, bioelectromagnetic interventions, and, in fact, a large number of CAM modalities.

A priori, it is difficult to categorize allopathic drug therapies, which may act either informationally or structurally. This depends on the rationale and mechanism of action of the particular drug.

In general, when a healthy organism is exposed to a weak stimulus such as that used in energy medicine, the response is usually negligible. This is because a nonlinear dynamic

system at homeostasis tends to remain there when a small fluctuation is imposed. However, if the organism is diseased or otherwise imbalanced, the response to a weak stimulus may be dramatic. It may dynamically nudge an unbalanced or sick organism directly into a new steady-state region associated with healing. On the other hand, it may send the sick organism into a region of greater instability and produce a healing crisis. This secondary imbalance further informs the organism and may promote other dynamic changes that lead to healing. Thus, chaos theory lends itself toward a scientific understanding of how CAM therapies may interact dynamically with bioregulatory processes to promote healing.

Homeostasis and homeodynamics

The idea of homeostasis has its origins in the ancient Greek roots of Western medicine (Grmek, 1999). In the nineteenth century, it was advanced further by French physiologist Claude Bernard, who is regarded by many as the founder of experimental medicine (Bernard, 1857). The term homeostasis, coined in the 1950s by Walter B. Canon, Ph.D., an American physiologist, describes the resistance of the organism to change, along with the maintenance of a stable internal environment, to allow proper functioning of its component cells, tissues, organs, and organ systems by constraining physical and chemical parameters to certain limits (Cannon, 1978).

Homeostasis, however, is based on classic physics, not modern biophysics. It is modeled in terms of mechanical feedback cycles similar to that by which a thermostat regulates temperature by switching a heater on and off. However, it is now recognized that there is no single or ultimate homeostatic balance point in biologic systems because they are self-organizing systems with many more possibilities than a single steady state. They also rely on dynamics other than feedback control such as strange attractors and innumerable flows of information to regulate themselves (Dell, 1982). Thus, the concept of homeostasis is limited and is undergoing replacement by a new concept, homeodynamics (Lloyd, et al., 2001; Yates, 1994). This new concept arose from the biophysical theories discussed here, namely, nonequibrium thermodynamics of open systems, self-organization, and chaos theory.

Homeodynamics takes into account the many modes of dynamic behavior exhibited by living processes in an ever-changing lifeline of the organism (Rose, 1997). The principle of homeodynamics states that physiological and biochemical processes help maintain the internal systems of the body (e.g., blood pressure, temperature, pH, etc.) in dynamic equilibrium, despite continuous environmental challenges and internal fluctuations in the natural dynamics of life. However, the dynamic range of what is considered optimal health is not a unique balance point, but varies, depending on the individuality of the organism—its unique biochemistry, history, and biologic age. Moreover, homeodynamic processes exhibit characteristic oscillations or periodicities, and there are a large number of these in an organism, each with different temporal features. For example, the flux of various ions across the cell membrane have particular periodicities. Many homeodynamic processes display circadian rhythms.

A critical aspect of homeodynamics is the capacity of living systems to respond creatively to stressors by developing new dynamic modes. When humans are exposed to environmental stressors or emotional challenges, there is a cascade of signal processing along with resulting physical changes in the body that initiate a response. Homeodynamics emphasizes the ever-adjusting nature of the processes that maintain life functions. Once a new stressor is encountered, the organism never returns to its previous dynamic state, but establishes a new dynamic balance appropriate to this newly integrated experience.

In homeodynamics, the processes that render dynamic stability proceed simultaneously at multiple levels of organization, from the molecular level to that of the whole being, and with various time scales. These processes are constantly adjusting to the myriad information flows and the entire lifeline or history of the organism. In this way, the organism integrates a huge number of information signals and responds appropriately. The biofield is proposed to act as a regulator of homeodynamics to coordinate life functions.

History of vitalistic concepts in science and medicine

It is acknowledged that the concept of the biofield, or any organizing field in biology, evokes shades of vitalism, an old philosophical concept that goes back to the 1600s (Bischof, 1994). Vitalism is the belief that life and organic substances differ fundamentally from the inorganic world because they contain a vital force. Vitalism suffered serious blows in 1845 when acetic acid, previously found only in organic matter, was synthesized by Kolbe from its constituent elements (Kolbe, 1845). In the 1890s the concept of a bioinformational field that guided embryogenesis in organisms was introduced by Driesch (Driesch, 1891) and in 1912 elaborated further by Gurvitch (Gurvitch, 1944). Weiss, in 1939, developed a similar concept to explain development (Weiss, 1939). Many other noteworthy biologists have promulgated biologic field theories to explain both biologic development and the integrity of organisms, including Yale biologist Harold Saxon Burr, Ph.D., who together with F.S.C. Northrup proposed an electrodynamic field underlying life (Burr and Northrup, 1939). A history of biologic field concepts in twentieth-century science was published in 1998 by Bischof (Bischof, 1998). Although such biologic field concepts were part of the mainstream for the first half of the twentieth century, as molecular biology grew more dominant from 1950 onward and developed into big business, a field perspective of life became taboo in academic science.

Despite its being ousted from science, vitalism has had a long history in medicine (Coulter, 1973). Vitalistic principles called by various names underlie many key concepts in CAM: *qi* in Chinese medicine; *prana* in Ayurvedic medicine; *ki* in Japanese medicine; and Wilhelm Reich's (M.D.) *orgone* in orgonomy, to name a few (Rubik et al., 1994a). Hahnemann (1755–1843), the father of classic homeopathy, wrote of the vital force (Hamlyn, 1979). Many schools of chiropractic hold vitalistic assumptions (Palmer, 1910), as do classic osteopathy and many other systems of medicine outside conventional Western medicine. Medical historian Harris L. Coulter, Ph.D. (Coulter, 1994) describes the 2500-year-old ongoing struggle between the vitalists and the mechanists in their healing philosophies. This philosophical difference remains one of the major schisms between conventional Western medicine and CAM.

The concept of subtle energy bodies is also integral to the ancient Eastern philosophical views of the human being that arose in India and China. Indian philosophy and Ayurvedic medicine maintain that, in addition to the physical body, there is a subtle body possessing various energetic anatomic structures, including the seven *chakras, nadis* (etheric channels), *pranas, vayus,* and *koshas* (yogic sheaths or bodies) (Leadbeater, 1927).

In Chinese philosophy and medicine, there are three important energy centers, called *dantians* that store and disperse *qi* from the *taiji* pole (center core) of the body (Johnson, 2000). The lower *dantian,* located in the lower abdomen, is connected with the *qi* field of the physical body. The middle *dantian,* located in the center of the chest, is connected with the *qi* field of the emotional body, surrounding the physical body. The third *dantian* is located inside the middle of the head and is associated with the spiritual field of *qi* that surrounds both the physical and emotional subtle bodies. *Qi* travels along the acupuncture meridians to all organs and tissues of the body.

The point here is not to prove or refute the existence of the subtle bodies of ancient medical systems. Rather, it is to point out that vitalistic concepts remain central today in virtually every indigenous system of medicine, including Oriental medicine, Ayurvedic medicine, modern chiropractic, classic osteopathy, homeopathy, and many other forms of CAM. It is the author's goal to introduce a field concept consistent with contemporary biophysics, the biofield, which may provide a unifying scientific foundation for CAM modalities resting on diverse vitalisic principles.

THE BIOFIELD HYPOTHESIS

Recently a small number of scientists including the author (Rubik, 1993, 1997b) have reintroduced the concept of a biologic field central to life. Tiller proposed the existence of a new force to explain certain features of life, in

addition to the other four known forces of physics (Tiller, 1993). Popp and colleagues proposed coherent states in organisms and the emission of coherent electromagnetic waves (Popp, 1996). Savva considered the biofield to go beyond electromagnetism, involving a nonphysical mental component that carries the information of intention and the psychic realm (Savva, 1997, 1998). Zhang called the biologic field the "electromagnetic body" and considered it to be a complex, ultraweak field of chaotic standing waves, a dissipative structure of electromagnetic fields that forms the energetic anatomic structures including the *chakras* and acupuncture meridians (Zhang 1995, 1996). Welch proposed metabolic field structures of space–time (Welch, 1992; Welch and Smith, 1990).

The biologic field is seen as a holistic or global organizing field of the organism by all these authors. Similar to the way a holographic plate distributes information throughout the hologram, the biologic field conveys information throughout the organism and is central to its holistic integration. The human biologic field is an organizing field within and emanating from the body, which hypothetically regulates the biochemistry and physiology of the body. The proposed biologic field is also a conceivable solution to the problem of how the information in an organism is stored beyond the genome. It must be said, however, that there is no consensus among scientists regarding the nature of the biologic field (i.e., whether it is electromagnetic or not, or whether it consists of electromagnetic components together with other uncharacterized fields).

In 1994, a panel on manual medicine modalities concerned with alternative and complementary medicine at the U.S. National Institutes of Health coined the term "biofield" (Rubik et al., 1994a) for the biologic field. The term "biofield" has been accepted by the U.S. National Library of Medicine as a medical subject heading search (MeSH) term. In 1999, the National Center for Complementary and Alternative Medicine at the U.S. National Institutes of Health (NIH) issued a Request for Application (RFA) for grant proposals dealing with biofield therapies such as Reiki, Therapeutic Touch, external *qi* healing, and other subtle energy interactions (NIH Web site). These NIH-sponsored research centers for Frontier Medicine in Biofield Science were established in 2002.

It is possible that there are subtle bodies of the human being beyond the physical body that involve realms of mind, soul, and spirit as espoused by Eastern philosophies. A full scientific model of the human being may indeed require elements that go beyond space-time, matter-energy, and require multidimensional geometry or other novel concepts. However, this paper takes only a first step in proposing a biofield hypothesis based on known scientific concepts from bioelectromagnetics and biophysical systems theory. The biofield is defined here as the endogenous, complex dynamic electromagnetic (EM) field resulting from the superposition of component EM fields of the organism that is proposed to be involved in self-organization and bioregulation of the organism. The components of the biofield are the EM fields contributed by each individual oscillator or electrically charged, moving particle or ensemble of particles of the organism (ion, molecule, cell, tissue, etc.), according to principles of conventional physics. The resulting biofield may be conceived of as a very complex dynamic standing wave (Rubik, 1997b; Zhang, 1995, 1996). It has a broad spectral bandwidth, being composed of many different EM frequencies, analogous to a musical symphony with many harmonics that change over time.

The biofield hypothesis offers a unifying hypothesis to explain the interaction of objects or fields with an organism, such as are used in certain CAM interventions. All objects radiate an EM field signature of resonant frequencies. If an object (such as a nutritional supplement, homeopathic, or drug) or externally applied EM field (such as that produced by a therapeutic electromagnetic device) is brought near to or inside the body of an organism, the frequencies radiated by the object (or applied EM field) would, in theory, interact with the organism's biofield. For example, it could modify, reinforce, destabilize, or otherwise interact with the biofield, by the principle of superposition of waves in the behavior of chaotic nonlinear dynamical systems. This would be the first step in mediating a biologic response.

As a holistic property of the organism, the biofield is proposed to regulate homeodynamic processes at multiple levels of organization from the molecular level upward to that of the whole organism. It orchestrates the activity of the organism's constituents through nonlinear systems dynamics described earlier. The biofield is similar to a conductor regulating the musicians playing a symphony. In this case, however, the conductor and the symphony are one and the same, because life is a self-organizing system. All the body constituents and their interactions give rise to the biofield, and the biofield in turn directs the functions of all the body constituents. A similar statement was made by Claude Bernard, who wrote, "the vital force directs phenomena that it does not produce; the physical agents produce phenomena that they do not direct" (Bernard, 1859).

Computing the biofield is an impossible task. The huge number of dynamic, interacting elements and their network of interactions transcend computational limits. Moreover, there have been no concerted efforts to date to measure the total endogenous EM field emitted by any organism. This is also a formidable, if not impossible, task, because there is a huge spectrum of frequencies involved that are extremely weak and time-dependent. Additionally, some measurements of the biofield would alter it. Nonetheless, certain elements of the human biofield have already been assessed under various conditions, including the electrocardiogram (ECG), electroencephalogram (EEG), and magnetoencephalogram (MEG). However, it must be said that conventional thinking regards these emissions as waste energy rather than informational fields playing an active role in bioregulation.

EVIDENCE SUPPORTING THE BIOFIELD HYPOTHESIS

Animal studies on regeneration

Experiments on regeneration in animals support a concept of the biofield in part as an endogenous electric field that informs the organism and orchestrates the regeneration process. In the early 1960s, the regeneration of salamander limbs was shown to be controlled by endogenous DC microampere currents flowing through the stumps (Becker, 1960, 1961). A positive current of injury flows for a few days after amputation that reverts to a negative potential as a blastema forms and regeneration is ensured, returning to its baseline potential when the limb is fully restored. By contrast, the frog, which does not spontaneously regenerate new limbs, produces a positive potential at the amputation site that remains positive until fibrotic healing of the stump is completed, when it returns to its baseline potential. However, a degree of limb regeneration can be induced both in the frog (Smith, 1974) and in the rat (Becker, 1972) by implanting a minute electrical battery and driving current through the stump. Reversal of the battery polarity causes tissue degeneration. More recent controlled studies in amphibians show that actively blocking the current of injury, which is of low amperage but significant voltage, inhibits limb regeneration (Jenkins et al., 1996). This suggests that bioelectrical factors are the critical controls of limb regeneration.

In studies conducted by Rose in the mid-twentieth century, kidney cancer cells of the frog were transplanted into salamander limbs where they grew into tumors and metastasized (Rose, 1948). The control animals with the cancer transplants died. In the test group, limb amputation was performed, and spontaneous regeneration occurred. Rose amputated the salamander limb through the primary tumor, leaving cancer cells behind in the stump. As the salamander began to regenerate its limb, the tumor mass disappeared, and the cancer cells dedifferentiated even more fully as the new limb formed. Then as the new leg grew, the former frog tumor cells redifferentiated along with the new limb cells. In biopsies performed later, the frog cells were easily distinguished from salamander cells by their smaller nuclei, and microscopic analysis showed frog muscle amid salamander muscle, frog cartilage cells amid salamander cartilage, etc. (Rose, 1948). No traces of cancer were found in the test animals. These data suggest the presence of a powerful organizing field activated during spontaneous limb regeneration that controls cellular dedifferentiation, redifferentiation, and cancer.

Thus, it appears that regenerative healing is not merely a local process, but a global one that mobilizes a primitive bioelectric control system distributed throughout the body that may be active in development, growth, and regeneration. Fully active in lower animals, it appears to be vestigial in mammals. Moreover, the natural healing of wounds leading to the scar tissue also involves electrical control of proliferation through changes in the DC potential of skin and currents of injury. Becker has pointed out that this same primitive DC bioelectric control system may be involved in the acupuncture system of meridians and points (Becker, 1974).

Some examples of indirect clinical evidence

Electrodermal testing and treatment. The biofield may be related to the system of acupuncture points and meridians, which have eluded anatomic approaches to locate them. A patient is assessed via electrodermal testing for acupuncture meridian and organ dysfunctions by measuring the variations in the electrical resistance of the acupuncture points. Then, when a substance that is the appropriate homeopathic remedy for a patient is brought near the patient's body, the electrical conductivity of the patient's acupuncture points that were previously abnormal immediately shifts to normal (Voll, 1975). Apparently the remedy is able to affect the electrical conductivity in the acupuncture meridians through the sample held by the patient or placed nearby the patient to influence the biofield. This method of selecting appropriate homeopathic remedies, nutritional substances, and other interventions using electrodermal testing is a CAM diagnostic and treatment method used by many practitioners worldwide.

VAS response. Practitioners use the vascular autonomic signal (VAS response) to assess food allergies and environmental sensitivities clinically. When an allergen is placed near the patient's ear, rich in acupuncture points, the substance emits resonant frequencies that inform the subject's biofield of this stressor. This leads to a change in tension of the peripheral artery smooth muscle that can be measured by monitoring the brachial artery pulse (Kenyon, 1982). Subtle changes in the pulse are assessed to discern positive, negative, and neutral stimuli, including drugs, homeopathic substances, and foods (Frinerman, 1999).

Applied kinesiology. This method of diagnosis and therapy purportedly determines health imbalances in the body by identifying weaknesses in specific muscles, and by means of activating or relaxing these muscles, health problems may also be resolved (Walther, 1988). One example from applied kinesiology is the bidigital O-ring test (Omura, 1982), whereby the patient touches the thumb with the index finger to make a ring. The practitioner tries to pull the fingers apart, while the patient tries to resist. The degree of resistance is assessed subjectively by the practitioner, who retests the patient again while he holds a sample medication. If the medication is indicated, the patient's power of resistance will then increase. Apparently the frequencies emitted from medicament and received informationally by the patient's biofield produce a change in the muscle strength.

Subtle stimulation of acupoints. The application of subtle influences to an acupoint produces changes in the body unrelated to neurophysiological or other known mechanisms. For example, the placement of magnets on acupoints with the magnet pole oriented in a certain direction has a different effect on distal acupoints than if the magnet polarity is reversed (Manaka et al., 1995). This suggests that not only the needling of acupoints, but extremely subtle stimuli such as the placement of magnets on them may be interacting with the biofield.

Reflexology. Stimulation of the reflex points and areas of the body allows them to send and receive specific information to and from other regions of the body. This stimulation may interact with the biofield, a holistic property of the body that conveys bioinformation. The specificity of action in reflexology may relate to boundary conditions of the biofield at certain tissue interfaces (Rubik, 1995b).

Evidence from geobiology

There is a deep interrelationship between geo-cosmic fields and life, because life evolved

in the presence of specific natural EM fields on earth (Tomassen et al., 1990). Evidence suggests that geophysical fields regulate life (Dubrov, 1978). Some of the natural frequencies associated with earth's Schumann resonance (Sentman, 1995), a transverse resonating waveband spanning between the earth and ionosphere, ranging from approximately 7 to 10 Hz, produce beneficial effects on many organisms, including humans, even at extremely low intensities. Consider that brain waves at 8 to 10 Hz form the alpha band of EEG, which is associated with relaxation and meditation. When EM fields in this frequency range are applied to the human, the brain is dynamically entrained at those frequencies, and the person goes into a psychophysiological state of relaxation. Organisms, in fact, may be stimulated by certain key frequency components of the geomagnetic field that act as pacemakers for their internal biologic oscillators.

Evidence from bioelectromagnetics

Bioelectromagnetics has demonstrated experimentally various biologic effects of extremely low-level nonionizing EM fields applied to organisms, ranging from small to robust. Positive, negative, and neutral effects have been observed (Blank, 1993; Polk and Postow, 1986). The empirically observed beneficial effects of EM fields (Brighton and Pollack, 1991) form the basis of bioelectromagnetic therapy. The technology of applying certain beneficial EM fields to the body to stimulate the natural healing response, known as bioelectromagnetic medicine, is a new form of CAM therapy (Rubik et al., 1994b). Specific EM fields have been identified that stimulate therapeutic effects such as osteogenesis, soft tissue regeneration, psychophysiological modulations, and immune system enhancement (Rubik, 1997a). One specific application is that extremely low-level (picoTesla) EM fields in the extremely low-frequency range (less than 100 Hz) have been applied successfully to treat Parkinson's disease (Sandyk and Derpapas, 1993). Another more widely used application is pulsed magnetic stimulation at 7 Hz, useful to promote bone tissue regeneration (Sharrard, 1990). This noninvasive treatment for bone fractures has been Food and Drug Administration (FDA) approved for more than 20 years.

Bioelectromagnetics research has uncovered a surprising fact. Extremely low intensity, nonionizing EM fields, having even less energy content than the physical thermal noise limit, can produce biologic effects (Adey and Bawin, 1977; Rubik et al., 1994b). At such extremely low levels, the energy content of the signal is even less than the random energy of molecular motion at physiological temperature. This means that such extremely low-level fields cannot act energetically on organisms, because the energy content is negligible. Thus, it has been proposed that they are acting informationally (Rubik et al., 1994b). Although there is no agreed on *modus operandi* of such stimuli, principles of nonequilibrium thermodynamics of nonlinear systems have been invoked, in which small stimuli play a key role as discussed previously. Fields carrying biologically relevant information have been called, "electromagnetic bioinformation" (Popp, 1988). It is proposed here that they interact directly with the biofield.

Therapies involving the application of extremely low-level EM signals may be providing EM bioinformation. This may occur through resonance or entrainment of specific frequencies. However, evidence shows that not just the frequency of the EM field, but other field parameters (Rubik et al., 1994b) including waveform, intensity, carrier frequency, modulation frequency, polarity, and time exposure patterns are involved in the specific biologic responses to externally applied EM fields. Particular values of these parameters make the difference between obtaining one biologic effect over another, or seeing no response whatsoever. Specifically configured EM fields thus appear to encode information in the dynamic wave train that is decoded by organisms. As yet, there is no accepted theory predicting the biologic response to a particular EM field. The responses, however, exhibit many properties predicted by nonequilibrium, nonlinear, chaotic systems theory. These include behaviors such as response thresholds, power and frequency windows of response, strange attractors, and hysteresis effects (Adey, 1990).

Some of the extremely low-level fields that have therapeutic action in bioelectromagnetic

medicine are similar in frequency and intensity to the endogenous fields of life (i.e., of components of the biofield). Many natural frequencies are emitted by the brain and heart, and externally applied fields at these same frequencies can cause entrainment and physiological, psychologic, and behavioral changes. Siskin and Walker (1995) have reviewed the healing effects of specific frequency windows, and some of them are as follows: 2 Hz, nerve regeneration; 10 Hz, ligament healing; 15, 20, and 72 Hz, stimulation of capillary formation and fibroblast proliferation. This suggests that EM bioinformation is fundamental to regulation of biologic function, and that it is encoded in the biofield. Thus, the natural oscillators in living systems themselves emit EM bioinformation regulating biologic function. In other words, cells and tissues may be "whispering" EM signals to one another and "listening" for relevant signals from their surroundings. The concept of EM bioinformation extends the conventional notion of information in biology to include that sensed by the higher order dynamics of living systems.

BIOINFORMATION AND A NEW COMMUNICATION SYSTEM

The concept of information in biomolecular science is based on biochemistry and conveyed by biomolecules, such as DNA, RNA, hormones, and receptors. However, the concept of information can be extended to biophysical models based on field interactions. Here we extend it to include EM bioinformation (i.e., information encoded in the dynamic wave train of low-level EM fields).

Information has taken on a mechanistic meaning in our age of computers, appropriate for machines, but questionable for life with its features of self-reference, self-organization, and consciousness. Machines have only a few critical internal interconnections, whereas living systems have an immense network of interconnections within, many dependent on the history, habits, and dispositions they have inherited or acquired. In living systems there are numerous pathways for information flow between the multiple levels of order, from the top-down as well as the bottom-up. From a nonmechanistic viewpoint appropriate for living systems, information is neither energy nor matter in itself, although energy or matter is its carrier. Information is that which exists only in relationship, and similar to energy, always involves at least two entities, a sender and a receiver, and it depends on the context. Information for a living system is that which "in-forms"; it conveys meaning, although the meaning to the organism may not always be conscious.

The complex network of information flows and exchanges in living systems is a novel way to conceptualize the living state. In other words, the living state is a multilevel informed and informing complex dynamic regulatory system. Information in biologic systems, herein called bioinformation to distinguish it from other mechanistic concepts of information, was proposed earlier by the author as a unifying concept of causation in living systems (Rubik, 1995a). As part of biologic regulation and maintenance of homeodynamics, cells and tissues may engage in continuous EM field sensing and exchange of information. This is proposed to be an inherent communication system in the organism based on waves, in which each constituent of life may serve as both antenna and receiver of information-carrying signals.

The following relates dynamic systems behavior to bioinformation. There is a broad spectral bandwidth of frequencies for the natural oscillators in the human body that are information-rich and hypothesized to govern system dynamics from the top-down. Perhaps the EM signals that organisms emit and receive from others comprise the original wireless communication system on earth. This communication system may be more fundamental than the nervous system as it may be faster and richer in information.

SOME IMPLICATIONS, PREDICTIONS, AND TESTS OF THE BIOFIELD HYPOTHESIS

Acupuncture

Science has failed to substantiate the acupuncture meridians and acupoints anatom-

ically. Instead, these may be energetic manifestations of the biofield. Moreover, acupoints have been shown to be special regions of higher electrical conductivity than the surrounding tissues (Becker, 1976). The rapid global responses of the organism to acupuncture suggests that its effects may not be entirely mediated by neurohumoral mechanisms, but may involve the biofield with its faster communication system and holographic features. The biofield hypothesis predicts that stimulating the acupoints would impact the biofield to carry bioformation rapidly and globally throughout the organism for its specific reception by distant tissues. Studies to measure the speed of signal transduction of stimuli through the acupuncture system could be done to measure whether bioinformation travels faster than through the nervous system. If indeed the acupuncture system of meridians and points is part of the biofield, and if EM waves are the means by which a signal moves through the acupuncture system, then the biofield hypothesis predicts that this signal will travel faster than the speed of nerve conduction (20 m/s), because EM signals in the body travel at nearly the speed of light (3×10^8 m/s).

Homeopathy

Homeopathic remedies can be clinically effective at extremely high potencies or dilutions where no molecules of the original mother tincture remain. Thus, molecular theory is inadequate to explain its *modus operandi*. However, there may be bioinformation stored in the substrate of the remedy that the patient needs. Structured water, or water that has stored EM bioinformation of the original substance dissolved in it, may be the active agent in classic homeopathy. Ludwig claims to have measured and compared a large number of the extremely low-frequency rhythms in humans with resonant frequencies in homeopathic remedies (Ludwig, 1987), using a spectrum analyzer sensitive to the millihertz range. The frequencies radiated by homeopathic remedies may initially interact directly with the biofield. The biofield hypothesis predicts that homeopathic remedies brought into the proximity of a patient might also be effective, as would as "electronic" homeopathy, in which the key EM bioinformation of a homeopathic remedy is delivered via carrier waves. This is consistent with results from Benveniste's laboratory exploring "digital biology" (Thomas et al., 1995) and clinical results from electroacupuncture according to Voll (EAV; Voll, 1980) whereby electronic remedies are delivered to patients.

Biofield therapies

The beneficial effects from laying-on of hands by those such as Reiki and other biofield practitioners may be mediated by means of EM bioinformation. For example, extremely low-level EM fields emitted from a biofield practitioner may impact the biofield of the patient therapeutically. Furthermore, some of these practitioners claim to sense irregularities within and around patients' bodies, possibly in the biofield. That is, their hands or other organs may serve as sensitive antennae for elements of the biofield. Because microbes treated by persons serving as sham practitioners in basic science experiments do not show beneficial effects above untreated controls (Rubik, 1996), the EM bioinformation emitted during laying-on of hands might be uniquely associated with psychophysiological states of the practitioner's intention. This could be studied by measuring the extremely low-level EM fields emanating from practitioners' hands during treatment compared to nontreatment tasks. It is anticipated that shifts in mental concentration, mood, and/or intention might produce changes in the biofields of practitioners.

Electromagnetic bioinformational aspects of certain structural medical interventions

Medical interventions considered structural such as surgery, may, in fact, impact the biofield and work structurally and bioinformationally on the organism. It has been found in a few controlled trials on surgery, for example, in a recent study on osteoarthritis of the knee, that the sham surgery group showed similar beneficial results as conventional arthroscopic surgery (Moseley, 2002). The beneficial results of sham surgery are presently considered as placebo effects. However, physical injury to tissue produces electrical currents of in-

jury, first described by Galvani in 1786, and later by others (Vodovnik and Korba, 1992). Thus, both sham and conventional surgery should alter the biofield by the resulting current of injury that arises in the surgical wound. In studies where beneficial results from so-called "placebo" surgeries are obtained, the positive results, at least in part, may be the result of regulatory influences on homeodynamics from changes in the biofield. The possible therapeutic effects of sham surgery beyond placebo may be explored by looking for outcome differences between different types of sham surgery for a given disorder, whereby the placebo response would be rendered constant. Such observed differences, if any, would be expected if the sham surgeries had different impacts on the biofield.

CONCLUSIONS AND DISCUSSION

The history of biology reveals different philosophic perspectives that have shaped biology and medicine over the centuries. The present dominant paradigm of molecular reductionism falls short of explaining the dynamic, self-organizing and self-restoring properties of living systems and their responses to many CAM therapies, especially those involving field principles. However, a biophysical view of life is emerging from dynamic nonlinear systems theory of open, far from equilibrium systems that offers a complementary perspective and embraces the complex, holistic, dynamic features of life as well as new electrodynamic and bioinformational interactions.

The biofield hypothesis is developed from this perspective. It has implications for the life sciences in general, predicting a new communication system in organisms that involves EM bioinformation. It has implications and explanatory power for CAM; it predicts that many CAM modalities act dynamically on bioregulation, rather than on structure–function relationships in the body. Moreover, it provides the rudiments of a scientific foundation for the energy medicine modalities of acupuncture, homeopathy, bioelectromagnetic therapies, and biofield therapies. The first stage in the *modus operandi* of these modalities is predicted to be an interaction with the organism's biofield, and the result is an effect on homeodynamics.

We cannot observe the biofield directly, isolate it, or analyze it comprehensively. We cannot compute it from first principles because of its complexity. In relation to this, there are many unobservable aspects of nature known only indirectly in physics by their effects. Fields are one example of this. Another example from physics is the curvature of space-time. Nonetheless, certain aspects of the biofield may be ascertained from careful measurements, and its properties elucidated through the existence of certain phenomena. In order to learn more about the human biofield and its proposed eminent role in health and healing, we need a "human energy project," a project similar to the Human Genome Project, with funding and the full commitment of the research community. The new centers for Frontier Medicine in Biofield Science recently funded by NIH mark an important step forward.

This paper advances the biophysical perspective of life with a succinct definition and hypothesis of the biofield, which offers a unified concept for the *modus operandi* of certain medical interventions. Some predictions are made, and certain aspects of the biofield hypothesis proposed here can be further examined for validity. Further work, both theoretical and experimental, is needed to more fully develop and test this hypothesis.

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